United States Marine Corps
School of Advanced Warfighting
Marine Corps University
2076 South Street
Marine Corps Combat Development Command
Quantico, Virginia 22134-5068

MASTER OF OPERATIONAL STUDIES

ACHIEVING PERSISTENT SURVEILLANCE THROUGH THE USE OF LIGHTER-THAN-AIR VEHICLES AS THEATER INTELLIGENCE, SURVEILLANCE, AND RECONNAISSANCE ASSETS

SUBMITTED IN PARTIAL FULFILLMENT
OF THE REQUIREMENTS FOR THE DEGREE OF
MASTER OF OPERATIONAL STUDIES

LIEUTENANT COLONEL JASON D. GREEN
UNITED STATES AIR FORCE

ACADEMIC YEAR 2006-2007

Mentor: ______________________________
Approved: ______________________________
Date: ______________________________

Report Documentation Page

Form Approved
OMB No. 0704-0188

1. REPORT DATE **2007**	2. REPORT TYPE	3. DATES COVERED **00-00-2007 to 00-00-2007**

4. TITLE AND SUBTITLE **Achieving Persistent Surveillance Through the Use of Lighter-Than-Air Vehicles as Theater Intelligence, Surveillance, and Reconnaissance Assets**	5a. CONTRACT NUMBER 5b. GRANT NUMBER 5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S)	5d. PROJECT NUMBER 5e. TASK NUMBER 5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) **United States Marine Corps,School of Advanced Warfighting, Marine Corps University,2076 South Street, Marine Corps Combat Development Command,Quantico,VA,22134-5068**	8. PERFORMING ORGANIZATION REPORT NUMBER
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)	10. SPONSOR/MONITOR'S ACRONYM(S) 11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release; distribution unlimited

13. SUPPLEMENTARY NOTES

14. ABSTRACT

15. SUBJECT TERMS

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT **unclassified**	b. ABSTRACT **unclassified**	c. THIS PAGE **unclassified**	**Same as Report (SAR)**	**28**	

Standard Form 298 (Rev. 8-98)
Prescribed by ANSI Std Z39-18

TABLE OF CONTENTS

EXECUTIVE SUMMARY iii

PREFACE iv

INTRODUCTION 1

BACKGROUND ON LTAVS 3

A POSSIBLE FUTURE ISR LANDSCAPE 6

A PROPOSED FUTURE: LTAVS AS THEATER-LEVEL ISR ASSETS 8

HOW TO MAKE A FUTURE WITH LTAVS A REALITY 14

CONCLUSION 15

APPENDIX 19

GLOSSARY 20

BIBLIOGRAPHY 21

DISCLAIMER

EXECUTIVE SUMMARY

<u>TITLE:</u> Achieving Persistent Surveillance Through the Use of Lighter-Than-Air Vehicles as Theater Intelligence, Surveillance, and Reconnaissance Assets

<u>AUTHOR:</u> Lieutenant Colonel Jason D. Green, United States Air Force

<u>THESIS:</u> Lighter-than-air vehicles (LTAVs) have the potential to offer great utility as joint intelligence, surveillance, and reconnaissance (ISR) platforms by virtue of their capability to provide persistent surveillance, through long-dwell coverage over areas of interest at relatively low cost.

<u>DISCUSSION:</u> The Department of Defense is at a crossroad in terms of exploring ways to conduct ISR in support of future battles. Existing space surveillance assets are aging and follow-on systems are plagued by cost overruns and cancellations. Furthermore current airborne ISR platforms, both manned and unmanned, do not offer a truly persistent surveillance. A solution to compensate for these current and anticipated deficiencies may be with LTAVs, which can stay aloft for weeks or months at a time to provide long-dwell coverage to support the collection of signals and imagery intelligence.

<u>CONCLUSION:</u> LTAVs, such as, aerostats, airships, or hybrids, if properly developed and integrated into the operational commander's bag of tools, could prove to be a complementary ISR asset by providing persistent ISR coverage at relatively low cost.

PREFACE

I developed an interest in intelligence, surveillance, and reconnaissance (ISR) platforms relatively late in my career as an Air Force intelligence officer. My early career revolved around providing unit-level intelligence support to pilots and crews flying A-10, F-15, F-16, and B-52 aircraft into harm's way. I endeavored to know everything about those platforms, from how they dispensed chaff and flares, what ordnance they preferred to use, to when they needed to refuel. I became an expert in blue force operations at the expense of knowing about the platforms that intelligence professionals own and operate. Upon returning to the U.S. Air Force Weapons School, I took it upon myself to learn about ISR platforms, both national and airborne, in order to improve my value to the Air Force as an intelligence officer. While not truly an expert on every ISR asset, I believe I am fairly knowledgeable, can tap into the right resources for additional expertise, and provide useful and timely advice on the employment of current ISR assets to support operations. To further expand my ISR knowledge, I have chosen now to focus on what it may offer us in the future. I am curious about what the next 15 years or so may hold for the shape of ISR platforms supporting the operational commander. LTAVs may offer some benefit in that direction. My original intent was to look at only aerostats as future ISR platforms; however, based on my research, examining LTAVs as a class of ISR platforms makes more sense logically to support the desired end state of providing the commander with the best possible intelligence.

ACHIEVING PERSISTENT SURVEILLANCE THROUGH THE USE OF LIGHTER-THAN-AIR VEHICLES AS THEATER INTELLIGENCE, SURVEILLANCE, AND RECONNAISSANCE ASSETS

We need to seek out and develop long-dwell sensors and pursue other emerging technology breakthroughs in sensor or platform capability. We must also develop technology to permit rapid data exploitation by users who need it most urgently. The combination of these improvements will enable us to achieve the goal of persistent surveillance.[1]

--Dr. Stephen A. Cambone, Former Under Secretary of Defense For Intelligence (USD-I)

INTRODUCTION

The twenty-first century has seen an increasing demand for intelligence, surveillance, and reconnaissance (ISR) in support of the spectrum of military operations, from combating adversaries to providing humanitarian relief. The Global War on Terror (GWOT), in particular, has resulted in a call to refocus the existing Cold War ISR architecture to adapt and more effectively provide support in a continuously changing asymmetric environment. Warfighters need ISR assets that can provide increased persistence, or the ability to dwell for long periods over intended areas of interest.[2] Existing ISR assets cannot currently provide this capability to commanders and decision makers.[3] The Department of Defense (DOD), however, realizes the importance of persistence and is shifting future collection strategy to support the transition from periodic reconnaissance to persistent surveillance.[4] The DOD defines persistent surveillance as

> A collection strategy that emphasizes the ability of some collection systems to linger on demand in an area to detect, locate, characterize, identify, track, target, and possibly provide battle damage assessment and re-targeting in near or real-time. Persistent surveillance facilitates the formulation and execution of preemptive activities to deter or forestall anticipated adversary courses of action.[5]

This ability to "linger on demand" is precisely the core competency we should target when planning the design of future collection systems in order to compensate for deficiencies in existing collection systems.

The existing national ISR architecture may be considered deficient for several reasons. National-level collection systems, primarily designed to target Cold War era foes such as China and the Soviet Union, are aging.[6] These systems were designed to support national and strategic decision makers and do not provide the flexibility current operational commanders must have. Additionally, the demand on national intelligence systems outstrips the capability to provide tailored intelligence to all customers. Furthermore, follow-on national intelligence systems require long lead-times to design, develop, and field, and are not effectively adapting to the continuously changing threat. One key indicator of this deficiency is the National Reconnaissance Office's (NRO) decision to cancel the optical portion of the Future Imagery Architecture (FIA) satellite program following numerous technical problems, delays, and increasing costs.[7]

One promising means to help meet the demand for persistent ISR is through the development of new platforms that leverage the latest technology to provide increased collection capability in the future. One such class of platforms may be lighter-than-air vehicles (LTAV). Generally thought of as unmanned aircraft, especially balloons or airships, LTAVs generate lift from the buoyancy of contained gases that are lighter than the surrounding air rather than from aerodynamic motion.[8] By design, LTAVs provide persistence though the ability to stay aloft for periods of time far exceeding that of manned aircraft and unmanned aerial vehicles (UAVs). LTAVs offer great potential to develop and field comparatively low-cost, flexible, persistent ISR platforms for operational level commanders to use in military missions.

The purpose of this paper is to demonstrate that within the next 15 years, LTAVs, employed as ISR platforms, could bring a unique intelligence collection capability to theater and component commanders during military operations through the means of persistent surveillance. This paper provides a background on LTAVs to increase the reader's understanding, predicts the composition of the ISR landscape of the future, proposes a future where LTAVs are theater ISR assets, and, finally, highlights potential ways to create a future with LTAVs.

BACKGROUND ON LTAVS

Before moving further, it is first important to more precisely examine LTAVs. LTAV is a term often used to broadly classify unmanned aircraft that achieve lift from buoyancy rather than aerodynamic, powered flight. There are three primary types of LTAV technology: aerostats, airships, and hybrids.[9] Aerostats include both tethered and free-floating balloons.[10] Airships are buoyant aircraft that can be steered and propelled through the air and stay aloft primarily by means of a cavity filled with a gas of lesser density than the surrounding atmosphere.[11] Hybrids may blend elements of different types of airships, often by combining characteristics of heavier-than-air (HTA) and LTA technology.[12] Many current designs sprung from technological ancestors.

Over the past 140 years, LTAVs have demonstrated increasing utility as ISR platforms. One of the first examples of using LTAVs to support intelligence collection occurred in 1794 when the French established the first air service using balloons as observation platforms.[13] Professor Thaddeus Lowe served as an aerial observer in a balloon supporting the Union Army during the American Civil War.[14] The U.S. employed surveillance balloons and blimps up through World War II, and even continued their use into the Cold War.[15] Aerostats returned to military service during Operation IRAQI FREEDOM (OIF), providing surveillance support to U.S. Marine Corps urban force protection efforts.[16] Additionally, the Department of Homeland Security demonstrated the ability to use LTAVs to collect intelligence in support of defending the southern U.S. border.[17] If the past is any indication, greater things are yet to come from LTAVs as technology improves, increasing their capability to operate in increasingly higher altitude environments for extended periods of time.

The most likely operating environment for employing persistent, long-dwell LTAVs as ISR assets would be in the realm the U.S. Air Force refers to as high altitude (HA). The Air Force Research Laboratory (AFRL) has identified HA, generally recognized as between 65,000 and 120,000 feet, as holding the greatest potential for ISR persistence in terms of collection for the technical intelligence (TECHINT) disciplines, which include imagery intelligence (IMINT), signals intelligence (SIGINT), and measurement and signature intelligence (MASINT).[18] Additionally, the geometry of ISR assets operating in this region may also offer a unique perspective for imagery collection capability in terms of the ability to provide both oblique and nadir looks of potential targets from several sensors. HA also simplifies deconfliction by moving ISR assets to a higher altitude block, well above that of traditional aircraft. Furthermore, it also provides sanctuary for assets from all but the most capable strategic surface-to-air missiles (SAMs) and fighter aircraft.

It is important and instructive to identify several critical pros and cons related to employing LTAVs as ISR assets in the future. This helps to ensure the benefits of using them will outweigh potential drawbacks. There are several key strengths that LTAVs offer over other existing ISR platforms. First, based on projected overall life-cycle costs, LTAVs are likely to be cheaper to design, build, and operate than national ISR assets and aircraft (including both manned and unmanned).[19] Second, compared to manned aircraft, LTAVs do not risk human lives to collect intelligence. Third, compared to national satellites, they are operationally flexible; LTAVs are fully recoverable after completion of an ISR mission over a collection area and sensors can be swapped out between operations to tailor the collection to the next mission, whether it is for IMINT or SIGINT. Fourth, while national satellites are restricted to their assigned orbits around the Earth, providing predictable windows for collection access, LTAVs can theoretically always be watching.[20] Real or perceived, the omnipresence of LTAVs, staring at targets from multiple vantage points, denies enemies the ability to operate around national collection windows. Currently, hostile nations may simply calculate the next U.S. national coverage windows and conduct operations they wish to hide when there is no ISR coverage. For example, with a cluster of IMINT LTAVs hovering high above, it may be possible to catch a country in the act of transferring weapons of mass destruction (WMD) to a second country. Fifth and finally, as LTAVs may potentially hover or float in place for potentially months at a time, they would offer a truly persistent ISR collection that national satellites and UAVs cannot match. Satellites orbiting the Earth can only offer finite windows in which to collect intelligence each day. UAVs, while enjoying lengthy on-station times approaching 36 hours, must routinely land for scheduled refueling and maintenance. While I have touched on several impressive potential capabilities that LTAVs can bring to the future battlespace, there are also drawbacks that are worth highlighting.

LTAVs do have some significant hurdles to overcome, if they are to become effective ISR platforms in the future. First, the technology behind LTAVs is not fully developed; however, based on DoD and industry estimates, workable LTAV prototypes can be designed and built within five years.[21] Second, LTAVs hovering over hostile territory in a HA environment may be vulnerable, like manned aircraft and UAVs, to strategic SAMs and enemy fighter aircraft. This may marginalize their initial utility in a conflict over a hostile country with a robust integrated air defense system (IADS), until those threats can be rolled back. Mitigation for this may be in the development and integration of self-protection systems into LTAVs to increase their survivability in such an environment.[22] By implication, this requires air supremacy over the battlespace. Third, unlike manned aircraft and UAVs, individual LTAVs are likely to be slow in terms of maneuvering into new positions in order to collect in different regions of the battlespace. This weakness may be overcome by employing a constellation, or grid, of LTAVs across the battlespace in width and depth, reducing the need to reposition assets. A constellation of continuously hovering LTAVs would also provide the ability to image anywhere, anytime in the hostile environment, or, in the case of SIGINT collection, offer the ability to triangulate threat emissions with multiple sensors to achieve improved location accuracy. Fourth, an LTAV may pose a potential danger to other aircraft if its station keeping system malfunctions or it breaks free from its tether and drifts. Fifth, weather could significantly impact LTA platforms and onboard sensors. Further research and development is needed to lessen such effects. The appendix contains an assessment of ISR platform technologies based on several criteria in terms of relative strengths and weaknesses.

Analysis of various platforms, including national satellites, manned aircraft, UAVs, and LTAVs indicates that an optimized mix of platforms, to include LTAVs, would ensure a future complementary capability to conduct ISR collection in support of military operations. LTAVs used in an ISR role would be more likely suited to specific ISR collection missions. Studies evaluating current LTA technology suggest that LTAVs may be best suited to support electro-optical (EO) and infrared (IR) IMINT collection operations. This does not, however, rule out potential developments for SIGINT and MASINT sensor capabilities on LTAVs.[23] Another interesting possibility may be to integrate the outer skin of an LTAV into a radar antenna array, allowing the vehicle to be used as a large radar intelligence (RADINT) platform.[24] LTAVs, perhaps a mix of aerostats, airships, and hybrids, equipped with IMINT sensors operating in an HA environment, could provide high-resolution images in real time, around the clock, for months at a time within a larger ISR landscape.

A POSSIBLE FUTURE ISR LANDSCAPE

Predicting what the ISR landscape of the future may look like is useful for a few reasons. First, it allows one to see what might be out there providing intelligence collection 15 years from now. Additionally, it may help to identify gaps or shortfalls in collection capabilities that have not yet been identified. This particular forecast indicates that, although specific types and numbers of assets may change, theater commanders will still have a mix of national and theater assets providing intelligence collection.

National intelligence assets, assessed as extremely expensive to design, build and operate, will always exist. Current national platforms will have been phased out and replaced by follow-on systems, including a reinvigorated FIA architecture. National assets will continue to primarily focus on providing global ISR coverage to support national decision makers; intelligence disciplines will likely include SIGINT, IMINT, and MASINT. Operational commanders will still be able to request tasking of national assets but there will be competition for scarce collection resources due to limited numbers of assets. National assets will not offer long-dwell, persistent coverage of the battlespace.

Manned ISR assets will likely experience a steady decline in terms of supporting military operations. UAVs pose the biggest competition to manned ISR platforms. The success of current UAVs like the RQ-4 Global Hawk and the RQ-9 Reaper in Operation IRAQI FREEDOM and the greater GWOT has proven there is little, if any, tangible value in putting humans in harm's way to collect quality TECHINT.[25] There are two potential exceptions to this decline. The RC-135 Rivet Joint, a manned SIGINT collection platform, will remain in the Air Force inventory until the 2020s. The E-8 Joint Surveillance Target Attack Radar System (J-STARS), will continue to provide ground moving target indicator information and synthetic aperture radar (SAR) IMINT.[26] Persistence will continue to be the Achilles' heel of manned platforms, with a limited number of assets available and human crews limiting on-station times to no more than 12 hours.

Use of UAVs in the military will almost certainly expand within the next 15. UAVs are combat proven and already in service. UAVs are operationally flexible; they are immediately responsive to changes on the battlefield and can be repositioned to more effectively support commanders. As already mentioned, UAVs do not risk human lives to collect intelligence. UAVs are less expensive than national systems to design, build, and operate. It is likely that individual services will continue to operate their own UAVs to provide intelligence collection in support of component-level and lower-echelon units. The notable exception will be the RQ-4 Global Hawk, which is replacing the manned U-2. The joint/combined forces air component commander (C/JFACC) will operate the RQ-4 to provide intelligence collection in support of the theater and other component commanders. The RQ-4 offers moderate persistence over the battlespace, with upwards of 36 hours of on-station time.

Thus far, none of the assets operating in this future landscape truly offers the kind of ISR persistence that Dr. Cambone encouraged us to seek.[27] This is where LTAVs can make a valueadded impact by bringing persistence and the ability to operate in an HA environment to effectively complement other ISR platforms in a synergistic manner over the battlespace.[28] Picture a fleet of LTAVs, probably a mix of tethered aerostats and station-keeping airships operating at high altitude, occupying mutually supporting positions over the battlespace. Sufficient assets, arrayed in a grid-like pattern across the battlespace, ensure overlapping and redundant coverage.

The addition of LTAVs to this landscape affords future commanders a more robust and persistent ISR capability, providing real-time intelligence from anywhere on the battlespace, whenever they need it.[29] LTAVs must be effectively integrated into the future ISR architecture.

A PROPOSED FUTURE: LTAVS AS THEATER-LEVEL ISR ASSETS

What follows is a potential concept of operations for employing LTA ISR assets in the future. This concept addresses, in as much detail as space allows, a potential ISR asset that is 15 years from being fielded. The result is a vision of capabilities that ISR LTAVs bring to the fight and how military collection might be enhanced to provide commanders of the future a realistic long-dwell, persistent surveillance capability.

This proposal makes several assumptions about LTAVs in order to achieve an environment where they serve as ISR assets. First, life-cycle funding to support LTAV programs “from cradle to grave” was obtained. Designers and engineers were able to improve technology to the point that LTAVs enjoy the following characteristics: they are cheap to make and operate, they are durable, they can operate for months at a time in an HA environment, they can maintain relative position via a tether or an on-board station-keeping mechanism, and they can be controlled beyond line-of-sight via a ground control station (GCS) located in theater or stateside. Additionally, designers were able to improve onboard sensors in terms of capability and miniaturization to the point that each vehicle could carry IMINT, SIGINT, and MASINT packages, if needed. Finally, joint and service doctrine, to include tactics, techniques, and procedures (TTPs), was rewritten to incorporate the employment and use of LTAVs as ISR assets.

LTAV Command and Control.

LTAVs would be employed at the theater level, providing theater and component commanders with a persistent, flexible ISR capability to complement national overhead assets, UAVs, and any remaining manned ISR platforms.[30] The Air Force, normally tasked with the role of being the J/CFACC, is a logical choice for operating LTAVs as ISR assets, on behalf of joint forces for several reasons. First, the Air Force's Transformation Plan articulates the need to have an ongoing effort to achieve persistent ISR over the battlespace. Second, LTAVs are aircraft. The Air Force is the service best prepared to develop and operate such aircraft in support of theater ISR collection. The J/CFACC is traditionally the supported commander for the theater ISR mission. LTAVs would provide the J/CFACC one more ISR capability operating in his airspace and under his control. Thus, airspace deconfliction would be easier with other aircraft operating in the same airspace. Additionally, the Air Force already possesses the infrastructure, doctrine, and TTPs for the theater air operations center and distributed common ground stations (DCGS) needed for both airborne command and control and ISR tasking, processing, exploitation, and dissemination (TPED) processes. Day-to-day management and oversight of LTA ISR assets would be the responsibility of the J/CAOC ISR Division Director. The RQ-4 Global Hawk offers the best current example of how LTAVs would be controlled and managed. Tactical control, to include movement, positioning, and repositioning of the assets, would be accomplished from a GCS embedded within the C/JFACC's DCGS and would be located stateside.

LTAV Assignment and Deployment.

LTAVs would be assigned to Air Force intelligence squadrons (IS). The ACC assigned to each regional combatant command would have an IS to provide LTAV operations. In support of non-crisis operations, it may be possible to launch LTAVs from stateside or other garrison locations, reducing potential deployment costs. If needed to support an immediate crisis, an LTAV IS could deploy anywhere military operations require ISR coverage, bringing their LTAVs from garrison locations to the theater of operations. Theater and continental US (CONUS) command logistics infrastructure will be in place and ready to support LTAVs. Upon arrival at deployment locations, IS personnel would inflate, launch, recover, and maintain LTA vehicles and associated sensors in support of the theater intelligence collection plan.

LTAV Employment Considerations.

LTAV employment plans would probably call for a grid-like constellation, possessing both width and depth, and a scalable expansion capability to provide 100 percent coverage of the required battlespace. Employment altitudes would range from 65,000 to 120,000 feet and could be tailored to take into account a variety of mission-related factors including required image resolution, potential threats, and type of product desired.[31] If the situation does not require synergy, LTAVs could also be individually employed.

From an IMINT perspective, LTAVs will be operating approximately 10 to 20 times closer to their planned targets than a satellite in a low-earth orbit (LEO) of 400 kilometers; this suggests that LTAV sensor optics will be 10 to 20 times smaller providing similar performance, or achieving 10 to 20 times better resolution with the same optics.[32] IMINT sensors would slew up to 45 degrees from center, providing multi-color, EO and IR images of intended collection targets.

LTAV SIGINT sensors would collect signals based on the theater collection plan and remote programming from the GCS.[33] To save weight, sensors would not process and archive signals onboard; instead they would transmit all collected data to the DCGS architecture for follow-on processing, exploitation, and dissemination. Use of SIGINT sensors on multiple LTAVS will allow SIGINT analysts using automated software tools to derive fairly precise emitter locations.

LTAVs operating in an HA environment could be vulnerable to air-to-air missiles (AAMs) launched from third and fourth generation fighter aircraft, such as the Su-30 MKI, or strategic SAMs, like the SA-5, SA-10, and SA-20.[34] Therefore, it may not be prudent to use LTAVs assets directly over the hostile terrain until after the IADS is rolled back. However, some studies have suggested that LTA assets may present low radar cross sections making them difficult to target with such radar-cued weapons.[35] In this case, it may then be possible to immediately position LTAVs within the battlespace, while ensuring assets are out of reach of potential threats.

The overall number of assets employed across the battlespace would vary based on the type of intelligence collected and the size of the area where persistent surveillance is required. However, ensuring 100 percent coverage of a large battlespace would require many more assets. If sufficient assets are not available to cover the entire battlespace, then 100 percent coverage could be provided over the areas of the battlespace determined to be the most critical and coverage could be adjusted as needed to suit the mission.

LTAV Incorporation into the ISR Architecture.

A critical point of concern for incorporating LTAVs into a potential theater ISR architecture will be how intelligence will be exploited and disseminated across the battlespace. The Air Force's Distributed Common Ground System (AF-DCGS) is designed to process and evaluate ISR data, and then disseminate the intelligence produced. DCGS is essentially a planned robust terrestrial and space communications backbone architecture that could be employed to manage LTAV ISR collection operations. DCGS currently supports existing ISR platforms including the RQ-4, the U-2, and RQ-1, and future upgrades could easily support LTAVs. The DCGS makes use of communications relays, eliminating the need to deploy IMINT and SIGINT analysts to operational theaters. Furthermore, DCGS is the program of record for TPED for all military services, making it the logical choice to support LTAV ISR operations.

LTAV collection assets would be tasked through a suite of web-based collection management tools running on the DCGS communications backbone. All theater intelligence organizations, including component commands and subordinate units, would have the ability to access and use tasking tools to submit requirements. The number of LTA assets and method in which they would be arrayed across the battlespace would significantly reduce competition for collection. Assets would be able to take any and all images required and collect SIGINT that meets programmed parameters.

Data collected by LTAV sensors, as well as other theater ISR assets, would be transmitted through over-the-horizon communications pipes and injected into a network-centric array of DCGSs around the world for post-collection image processing. The DCGS design emphasizes reachback, eliminating the need to have intelligence exploitation assets in-theater. IMINT and SIGINT specialists assigned to DCGS units around the world, including those stateside, would exploit data collected and post intelligence products in near-real time on servers for access by customers. Dissemination of intelligence products would follow either pull or push concepts; theater intelligence organizations could simply surf to websites to retrieve intelligence products, or have them electronically delivered.

Potential Operational Implications of LTAVs.

As with all future concepts seeking sponsorship and funding, it is important to examine some potential operational implications to establish the unique and improved capabilities LTAVs could provide in the future battlespace. Employing a grid of LTAVs high over a future battlefield offers several solutions to existing deficiencies within the ISR realm. Although there are myriad operational implications with respect to LTAVs, this discussion is limited to two of the more likely ones:

simultaneous imaging from multiple sensors within an LTAV sensor grid, and advanced cross-cueing capabilities.[36]

Current imaging sensors available to the battlefield commander do not offer true persistence. An asset like the RQ-4 Global Hawk can stay aloft for an extended duration, but is only able to image one direction at a time and is unable to stare at a target simultaneously from multiple vantage points, unless multiple RQ-4s are airborne. A grid of IMINT-capable LTAVs could solve this problem. An LTAV directly above a target could take images from a nadir view. If the resultant images show obscuration, the neighboring sensors in the grid could be triggered automatically to slew toward the target to collect additional images from oblique views. This complementary collection could essentially look inside a hangar to see an aircraft or identify enemy ground vehicles hiding in a grove of trees to compensate for the inability to collect from the nadir view. An additional advantage of simultaneous collection from multiple vantage points is the increased amount of data collected on the target. Currently, intelligence analysts construct three-dimensional (3D) target models from scant intelligence, forcing them to extrapolate additional target characteristics based on previous experience and knowledge. Multiple simultaneous target views could assist intelligence analysts in building more accurate and detailed 3D target models of hardened facilities allowing for more effective weapons employment.

Another likely implication of LTAVs would be the ability to cross-cue sensors within the grid. In a future ISR construct, SIGINT sensors aboard LTAVs would collect a wide variety of signals emanating across the battlespace. Signals matching threats such as SAM radars, counter battery fire radars, or cell phones used by insurgents would tip additional SIGINT sensors within the grid to more accurately geo-locate the source of the signal. LTAV IMINT sensors hovering above the threat could then automatically slew and capture images. The resultant coordinates could then be uplinked to orbiting UAVs assigned a hunter-killer role for weapons employment, greatly shortening the kill chain.

HOW TO MAKE A FUTURE WITH LTAVS A REALITY

If theater and operational commanders are to have persistent ISR coverage of the future battlespace, it will likely be through a mix of ISR systems offering synergistic collection capabilities. The development and incorporation of LTAVs into a future ISR architecture is one possible option. In order for this to become a reality, progress must be made in several key areas including funding, technology, and doctrine.

Despite signs that overall life-cycle costs for LTAVs are relatively low, obtaining funding for new programs could be problematic.[37] Advocates representing the intelligence and military operations communities must step forward to persuasively convince members of Congress of the potential benefits of LTAVs.

Funding LTAV programs could also help progress in the second area, which is technology. LTAVs, compared to manned aircraft, are in their infancy. Numerous advances must be made in the areas of airframe design, payload improvement and miniaturization. Most studies indicate that airframe technology demonstrators are feasible within five years. This would provide an additional five to seven years of refinement and testing before initial production. Existing payload technology, such as UAV SIGINT or IMINT packages, is fairly robust, but could be further refined and miniaturized to reduce weight in the intervening time while airframe technology is being developed.

Incorporating developing concepts, such as LTAVs, into doctrine is an equally important key area in which to concentrate effort. Ideally, efforts should initially focus on adapting existing ISR and collection management doctrine to incorporate changing technology. This can be accomplished as LTAVs are undergoing the various stages of design, testing, and fielding. Doctrine should also include TTPs on the actual employment of LTAVs to support theater ISR collection operations. Furthermore, efforts should be undertaken within the DOD's Joint Requirements Oversight Council (JROC) to accurately establish what persistent surveillance is and how current and planned ISR assets measure up in pursuit of satisfying that capability. This will help to serve the acquisition process by aiding in establishment of quantifiable milestones required to develop and field LTAVs.

CONCLUSION

Although not currently ready for prime time, the concept of using LTAVs as ISR platforms above the tactical level offers the promise of enhanced future ISR collection for joint forces around the globe. LTAVs would effectively complement a future ISR architecture, which would likely include a mix of manned, aircraft, UAVs, and national satellites, by providing a persistent, flexible, and relatively inexpensive platform for commanders at the operational level of war. However, to achieve this possible future, we must chart a course by obtaining funding support, stimulating the development of LTA technology, and drafting doctrine that truly leverages and embraces the coming potential for persistent surveillance of the battlespace. The systematic approach of collecting intelligence by periodically sampling the battlespace no longer provides commanders the situational awareness needed to decisively defeat the enemy. We need persistence; LTAVs will help provide that capability.[38]

---

[1]Dr. Stephen A. Cambone, Under Secretary of Defense For Intelligence, "Intelligence, Surveillance, & Reconnaissance," Statement before the Senate Armed Services Committee, Strategic Forces Subcommittee, 7 April 2004, URL: <www.shaps.hawaii.edu/security/us/2004/20040407_cambone.html>, accessed 22 November 2006.

[2]Headquarters Air Force (HAF), *Transformation Division (XPXT), The USAF Transformation Flight Plan FY03-07*, Washington DC: HAF, November 2003. URL: <www.dtic.mil/jointvision/af_trans_flightplan .pdf>, accessed 22 August 2006, xi.

[3]Edward Tomme, Lt Col, USAF, *Near-Space as a Combat Effects Enabler*, CADRE Quick-Look 04-25, College of Aerospace Doctrine, Research and Education (CADRE), (Maxwell AFB, AL: Air University, 2004). URL: < www.au.af.mil/au/awc/awcgate/cadre/ari_ql2004-25.pdf>, accessed 19 November 2006, 2. Cited hereafter as Tomme, *Near-Space*.

[4]John R. Landon, Deputy to the Assistant Secretary of Defense (Networks and Information Integration) for Command and Control, Communications, Intelligence, Reconnaissance and Surveillance, and Information Technology Acquisition, Statement on the Aerial Common Sensor Program, Presented to the U.S. House of Representatives Subcommittee on Tactical Air and Land Forces Committee on Armed Services and the Subcommittee on Technical and Tactical Intelligence, Permanent Select Committee on Intelligence, October 20, 2005, URL: <www.dod.mil/cio-nii/docs/ACSP.pdf>, accessed 9 December 2006; In this statement, Mr. Landon says the Defense Department defines persistent surveillance as the integrated management of a diverse set of collection and processing capabilities, operated to detect and understand the activity of interest with sufficient sensor dwell, revisit rate and required quality to expeditiously assess adversary actions, predict adversary plans, deny sanctuary to an adversary, and assess results of US and coalition actions.

[5]The Joint Staff, *DOD Dictionary of Military and Associated Terms,* Joint Publication 1-02, Washington, DC: GPO, 12 April 2001 (as amended through 14 April 2006), URL: <www.dtic.mil/ doctrine/jel/doddict/data/p/04074.html>, accessed 28 November 2006, 410.

[6]Mark M. Lowenthal, *Intelligence: From Secrets to Policy*, 1st ed, Washington, DC: CQ Press, 2000, 50.

[7]Edmund H. Nowinski and Robert J. Kohler, "The Lost Art of Program Management in the Intelligence Community," *Studies in Intelligence*, Vol 50, no. 2, Washington DC: GPO, 2006, URL: <www.odci.gov/csi/studies/vol50no2/83965Webk.pdf>, accessed 22 November 2006; Monica Montoya, Military Utility Analyst, AFRL/VSES, Kirtland AFB, NM, "Future War Paper for SAW," Email to author, accessed 20 April 2007. Monica Montoya points out that a DoD initiative known as Operationally Responsive Space is pushing for modularly designed, assembled and rapidly launched micro-satellites to in part compensate for problems with FIA and may also may factor into a future ISR architecture. They are likely to have longer mission durations than existing airborne ISR platforms and may be able to rapidly shift their focus to other areas of the globe, depending on the configuration of the constellation.

[8]Author's analysis; Christopher Bolkcom, *Potential Uses of Airships and Aerostats*, Congressional Research Service (CRS) Report for Congress, # RS211886, Washington, DC: GPO, 11 November 2004, 4-6. Cited hereafter as Bolkom; Don Hard, Maj Gen, USAF (Ret), National Defense Industrial Association (NDIA) Near-Space Summer Study, Final PowerPoint Briefing presented to the Under Secretary of the Air Force for Space, Summer 2006, slide 7. Cited hereafter as Hard.

[9]Bolkom, 4-6.

[10]Bolkom, 1, 4.

[11]Bolkom, 1, 5.

[12]Bolkom, 5-6.

[13]U.S. Centennial of Flight Commission, "Aviation History Facts: April," web-only essay, URL: <www.centennialofflight.gov/user/fact_apr.htm>, accessed 22 October 2006.

[14]F. Stansbury Hayden, *Military Ballooning during the Early Civil War*, Baltimore, MD: Johns Hopkins University Press, 1968.

[15]Judson Knight, "Balloon Reconnaissance, History," web-only essay, URL: <www.answers.com/ topic/balloon-reconnaissance-history>, accessed 17 April 2007.

[16]U.S. Marine Corps Warfighting Lab, *Campaign Plan 2006*, Web-only document, URL: <www.mcwl.usmc.mil/mcp/Chapts%201-4_6,%207/MCP-Ch%203-TechDev%2010%20Jul%2006.pdf>, accessed 3 December 2006, III-3.

[17]Bolkcom, 2.

[18]John Ard, Maj, USAF, Headquarters Air Staff (HAF), Directorate of Operations (A3), High Altitude Operations (HA OPS) (Near Space) Demonstrations, bullet background paper, Washington, DC: The Pentagon, 25 Aug 06; John Ard, Maj, USAF, Headquarters Air Staff (HAF), Directorate of Operations (A3), *Near Space*, PowerPoint briefing presented to U.S. Congresswoman Heather Wilson, no date listed, slide 6; Tomme, *Near-Space*, 1.

[19]Bolkcom, 6. Author's Note: Most space missions launching ISR assets into orbit have additional payloads on them; according to Monica Montoya this will certainly be the case for tactical satellites. To accomplish an accurate life-cycle cost comparison, other non-ISR missions, such as communications, navigation and weather, would need to be factored out.

[20]Author's Note: The ability to "always be watching" does not apply uniformly across the board to all intelligence disciplines. It is accurate to say that SIGINT, synthetic aperture radar IMINT, and some forms of MASINT can continuously collect. EO and IR IMINT sensors on LTAVs would need to be more like full-motion video imaging sensors on current UAVs to accomplish this. Additionally, EO and IR cannot see through weather or other obscuration.

[21]Hard, slides 24-27, 37.

[22]Author's Note: LTAVs could be equipped with a self-protection suite to increase survivability. Ideally, it would be able to jam air and air defense radars, deceive infrared missile seekers, dispense chaff and flares, and fire lasers against missiles in the end game. The biggest problem to solve would be to balance the lift capability of the LTAV with the weights of the self-protection suite and the onboard sensors.

[23]Hard, slide 24.

[24]Alan Michael Lyons and Carsten Metz, Inventors, Lucent Technologies Inc., "Light-weight signal transmission lines and radio frequency antenna system," US Patent, Issued 22 August 2006, URL: <www. patentstorm.us/patents/7095377-description.html>, accessed 16 April 2007.

[25]Author's Note: The author makes this assumption based on the emphasis of future Air Force systems such as the Unmanned Combat Aerial Vehicle (UCAV) and current ISR platforms including the RQ-4 Global Hawk and MQ-9B Reaper; this is by no means an assertion that there will be no manned aircraft within 15 years.

[26]Until recently the Air Force's acquisition strategy called for a single aircraft, the E-10 Multi-Sensor Command and Control Aircraft (MC2A), to replace both the E-3 Airborne Warning and Control System (AWACS) and the E-8 J-STARS.

[27]Author's Note: Dr. Cambone was the USD-I during the period when the majority of this paper was written. He has since resigned and Lieutenant General James Clapper, USAF (Ret.) has been nominated to replace him. General Clapper has not made recent statements regarding the utility of ISR persistence, however, statements he made as Director of the National Geospatial-Intelligence Agency (NGA), were in line with those of Dr. Cambone.

[28]Don Hard, Maj Gen, USAF (Ret), National Defense Industrial Association (NDIA) Near-Space Summer Study, Final PowerPoint Briefing presented the Under Secretary of the Air Force for Space, Summer 2006, slide 28. Cited hereafter as Hard.

[29] Author's Note: "Robustness" is a relative concept. It would depend the number and types sensor packages the LTAVs carry onboard that are available to the commander in support of ISR.

[30]Author's Note: This does not preclude use of LTAVs in a tactical role to supporting maneuver forces or enhancing force protection.

[31] Author's Note: An interesting capability worth further exploration would be the ability of the LTAV grid to dynamically adjust its altitude based on the needs of the collection requirements levied in order to collect intelligence of the highest quality. Other mitigating issues, such as weather, winds, and threats, would also need to factor into this equation.

[32] Edward Tomme, Lt Col, USAF, *The Paradigm Shift to Effects-Based Space: Near Space as a Combat Effects Enabler*, Research paper 2005-01, College of Aerospace Doctrine, Research and Education (CADRE), (Maxwell AFB, AL: Air University, 2005), URL: <www.au.af.mil/au/awc/awcgate/cadre/ari_2005-01.pdf>, accessed 22 August 2006, 12.

[33]Author's Note: The Intelligence Community currently defines MASINT as "technically derived intelligence (excluding traditional imagery and signal intelligence) which when collected, processed, and analyzed, results in intelligence that detects, tracks, identifies, or describes the signatures (distinctive characteristics) of fixed or dynamic target sources." In other words, it is typically derived after the fact by fusing data from other INTs. For this reason, there is no planned MASINT sensor in this concept. MASINT will be produced within the terrestrial DCGS architecture from multiple sources. Definition Source: Permanent Select Committee on Intelligence, House of Representatives, "VII. MASINT: Measurement and Signatures Intelligence*"* in *IC21: The Intelligence Community in the 21st Century*, Staff Study, One Hundred Fourth Congress, Washington, DC: GPO, 1996. URL:<www.gpo.gov/congress/house/intel/ic21/ic21007 .html>, accessed 1 December 2006.

[34]Author's Note: A combination of extremely high altitude and low velocity may actually help to protect an LTAV. Third and fourth generation aircraft radars and many SAM radars rely on measuring Doppler shift of radar returns to help with targeting. A weakness inherent to Doppler radar is that stationary or extremely low speed targets are filtered out to reduce radar clutter and thus may be able to "hide" from fighter and SAM radars.

[35]Bolkcom, 4-5.

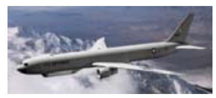
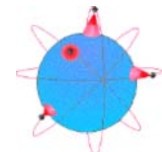
[36]Author's Note: Future researchers may want to expand further beyond the two operational implications provided. One such area of exploration may revolve around the ability of any ISR customer in the battlespace being able to immediately retask sensors needed to provide real-time intelligence without impacting ongoing collection for other customers; essentially this would be an ISR network able to adjust and compensate all its tasking requirements simultaneously and meet all collection requirements levied against it due to the quantity, quality, and position of available sensors in the LTAV grid.

[37]Tomme, *Near-Space*, 2.

[38]Jason M. Brown, Major, USAF, Student, Marine Corps Command and Staff College, Marine Corps Base Quantico, VA, "SAW Future War paper," Email to author, accessed 19 April 2007.

APPENDIX

Note: This appendix provides the relative strengths and weaknesses of likely future ISR platforms as determined by the author based on research conducted.

	LTA Vehicles 	Manned Aircraft 	UAVs 	Micro Satellites 	National Assets 
Description	Platforms ranging from aerostats, airships, to hybrid airships	Upgraded versions of existing aircraft such as the RC-135 Rivet Joint and E-8 J-STARS	Upgraded versions of existing remotely piloted ISR collection platforms such as RQ-4 Global Hawk	Small LEO satellites such as SurreySat's TopSat (pictured)	Follow-on to existing assets
Primary Customers	Theater Commanders	Individual Warfighting Components	Individual Warfighting Components	Theater Commanders	National Decision Makers; theater and subordinate commanders can task.
Asset Control	C/JFACC in support of theater and other component commanders.	Individual Warfighting Components	Individual Warfighting Components	Theater Command or JFACC.	National Intelligence Community
Persistence	Medium/High; ranges from days to weeks to months	Low; depends on human crew limitations	Low/Medium; approaching 36 hours	Medium; approximately 30 days.	Low/Medium; daily revisit capability
Risk to Humans	N/A	Medium/High	N/A	N/A	N/A
Asset Risk in High Threat Environment	Low/Medium	Medium/High	Medium /High	Low	Negligible
Operating Cost	Low/Medium	Medium/High	Medium	Medium/High	High
Forward Basing Footprint	Low/Medium	High	Low/Medium	Low	Low
Image Sources (left to right): ISIS HAA, Raytheon, Inc.; J-STARS, USAF; RQ-4, USAF.; TopSat, Surrey Satellite Technology Limited (SSTL); Satellites in LEO, CompassRose International, Inc.					

GLOSSARY

A2	Directorate for Intelligence (Air Force)
AAM	Air-to-Air Missile
ACC	Air Component Commander
AF-DCGS	Air Force Distributed Common Ground System
AFRL	Air Force Research Laboratory
C2	Command and Control
COMINT	Communications Intelligence
CONUS	Continental United States
DCGS-A	Distributed Common Ground System-Army
DCGS-M	Distributed Common Ground System-Marines
DCGS-N	Distributed Common Ground System-Navy
DGS	Deployable Ground Station
DOD	Department of Defense
EO	Electro-Optical
FIA	Future Imagery Architecture
GCS	Ground Control Station
GWOT	Global War on Terror
HA	High Altitude
HTA	Heavier-Than-Air
IADS	Integrated Air Defense System
IMINT	Imagery Intelligence
IR	Infrared
IS	Intelligence Squadron
ISR	Intelligence, Surveillance, and Reconnaissance
J-STARS	Joint Surveillance Target Attack Radar System
C/JFACC	Combined/Joint Forces Air Component Commander
LEO	Low Earth Orbit
LTA	Lighter-Than-Air
LTAV	Lighter-Than-Air Vehicle
MASINT	Measurement and Signatures Intelligence
NRO	National Reconnaissance Office
OIF	Operation IRAQI FREEDOM
SAM	Surface-to-Air Missile
SAR	Synthetic Aperture Radar
SIGINT	Signals Intelligence
TECHINT	Technical Intelligence
TPED	Tasking, Processing, Exploitation, and Dissemination
UAV	Unmanned Aerial Vehicle
USAF	United States Air Force
USD-I	Under Secretary of Defense For Intelligence
WMD	Weapons of Mass Destruction

BIBLIOGRAPHY

Air Combat Command (ACC). "Tethered Aerostat Radar System (TARS) Factsheet." ACC Website. URL: <www.acc.af.mil/library/factsheets/factsheet.asp?id=3866>, accessed 20 August 2006.

Allen, Edward H. "The Case for Near Space." *Aerospace America*, online ed., February 2006. URL: <www.aiaa.org/aerospace/images/articleimages/pdf/AA_Feb06_VP.pdf>. Accessed 30 August 2006.

Ard, John, Maj, USAF, Headquarters Air Staff (HAF), Directorate of Operations (A3). *High Altitude Operations (HA OPS) (Near Space) Demonstrations.* Bullet Background Paper, Washington, DC: The Pentagon, 25 Aug 06.

Ard, John, Maj, USAF, Headquarters Air Staff (HAF), Directorate of Operations (A3). *Near Space*. PowerPoint briefing presented to Congresswoman Heather Wilson. No date listed.

Bolkcom, Christopher. *Potential Uses of Airships and Aerostats*. Congressional Research Service (CRS) Report for Congress, # RS211886. 11 November 2004.

Brown, Jason M, Major, USAF, Student, Marine Corps Command and Staff College, Marine Corps Base Quantico, VA. "SAW Future War Paper." Email to author. Accessed 19 April 2007.

Cambone, Dr. Stephen A., Under Secretary of Defense For Intelligence. "Intelligence, Surveillance, & Reconnaissance." Statement before the Senate Armed Services Committee, Strategic Forces Subcommittee, 7 April 2004. URL: <www.shaps.hawaii.edu/security/us/2004/20040407_cambone.html>. Accessed 22 November 2006.

Hard, Don, Maj Gen, USAF (Ret). *National Defense Industrial Association (NDIA) Near-Space Summer Study*. Final PowerPoint Briefing presented the Under Secretary of the Air Force for Space, Summer 2006.

Hayden, F. Stansbury. *Military Ballooning during the Early Civil War*. Baltimore, MD: Johns Hopkins University Press, 1968.

Headquarters Air Force (HAF), Transformation Division (XPXT). *The USAF Transformation Flight Plan FY03-07*. Washington DC: HAF, November 2003. URL: <www.dtic.mil/jointvision/af_trans_flightplan.pdf>. Accessed 22 August 2006.

Jamison, Lewis, Geoffrey S. Sommer, and Isaac R. Porche III. *High-Altitude Airships for the Future Force Army*. Technical Report, (Santa Monica, CA: Rand Corporation, 2005). URL: <www.rand.org/pubs/technical_reports/2005/RAND_TR234.pdf>. Accessed 22 August 2006.

The Joint Staff. *DOD Dictionary of Military and Associated Terms*, Joint Publication 1-02. Washington, DC: GPO, 12 April 2001 (as amended through 14 April 2006). URL: <www.dtic.mil/doctrine/jel/doddict/data/p/04074.html>. Accessed 28 November 2006.

Keys, Lt Gen Ronald E., Deputy Chief of Staff, Air & Space Operations, US Air Force (USAF). *Statement on Unmanned Systems*. Presented to the TACAIR and Land Subcommittee, House Armed Services Committee, United States Congress, March 9, 2005. URL: <www.house.gov/hasc/testimony/109thcongress/TacAir%20Land/3-9-05KeysAF-UAV.pdf>. Accessed 15 July 2006.

Knight, Judson. "Balloon Reconnaissance, History." Web-only essay. URL: <www.answers.com/topic/balloon-reconnaissance-history>. Accessed 17 April 2007.

Landon, John R., Deputy to the Assistant Secretary of Defense (Networks and Information Integration) for Command and Control, Communications, Intelligence, Reconnaissance and Surveillance, and Information Technology Acquisition. *Statement on the Aerial Common Sensor Program.* Presented to the U.S. House of Representatives Subcommittee on Tactical Air and Land Forces Committee on Armed Services and the Subcommittee on Technical and Tactical Intelligence, Permanent Select Committee on Intelligence, October 20, 2005. URL: <www.dod.mil/cio-nii/docs/ACSP.pdf>. Accessed 9 December 2006

Lowenthal, Mark M. *Intelligence: From Secrets to Policy*, 1st ed. Washington, DC: CQ Press, 2000.

Lyons, Alan Michael and Carsten Metz, Inventors, Lucent Technologies Inc., "Light-weight signal transmission lines and radio frequency antenna system." US Patent, Issued 22 August 2006. URL: <www.patentstorm.us/patents/7095377-description.html>. Accessed 16 April 2007.

McCarter, Mickey. "Boost for Cruise Missile Defense." *Military Aerospace Technology*, online ed., 25 June 2004. URL: <www.military-aerospace-technology.com/article.cfm?DocID=521>. Accessed 1 October 2006.

Montoya, Monica, Military Utility Analyst, AFRL/VSES, Kirtland AFB, NM. "Future War Paper for SAW." Email to author. Accessed 20 April 2007.

Naval Research Advisory Committee. *Lighter Than-Air Systems for Future Naval Missions*, PowerPoint Briefing presented at the Pentagon to flag officers and senior executive service, 4 October 2005. URL: <www.onr.navy.mil/nrac/docs/2005_brief_lighter_than_air.pdf>. Accessed 15 Aug 2006.

Nowinski, Edmund H. and Robert J. Kohler. "The Lost Art of Program Management in the Intelligence Community." *Studies in Intelligence*, Vol 50, no. 2, 2006 (Washington DC: GPO). URL: <www.odci.gov/csi/studies/vol50no2/83965Webk.pdf>. Accessed 22 November 2006.

Pendall, David W., Major, U.S. Army. "Persistent Surveillance and Its Implications for the Common Operating Picture." The U.S. Army Professional Writing Collection. Web-only essay, March 2006. URL: < ://www.army.mil/professionalwriting/volumes/volume4/march_2006/3_06_3.html>, accessed 22 November 2006.

Permanent Select Committee on Intelligence, House of Representatives. "VII. MASINT: Measurement and Signatures Intelligence" in *IC21: The Intelligence Community in the 21st Century*, Staff Study, One Hundred Fourth Congress, Washington, DC: GPO, 1996. URL: <www.gpo.gov/congress/house/intel/ic21/ic21007.html>, accessed 1 December 2006.

Sams, Ronald F., Major General, USAF, Director of Intelligence, Surveillance and Reconnaissance, Department of the Air Force. *Testimony on Air Force Fiscal Year 2005 ISR Programs*. Presentation to the Senate Armed Services Committee, United States Senate, April 7, 2004. URL: <www.fas.org/irp/congress/2004_hr/040704sams.pdf>. Accessed 1 October 2006.

Stephens, Hampton. "Near Space." *Air Force Magazine*, online ed., July 2005. URL: <www.afa.org/magazine/July2005/0705near.asp>. Accessed 15 August 2006.

"Stratellite Capabilities." Sanswire Networks Website. URL: <www.sanswire.com/capabilities .htm>. Accessed 26 August 2006.

Tether, Tony, Ph.D., Director Defense Advanced Research Projects Agency (DARPA). Statement to the Subcommittee on Terrorism, Unconventional Threats, and Capabilities, House Armed Services Committee, United States Congress, 10 March 2005. URL: <www.darpa.mil/ body/news/2005/darpa_hasc_3_10_05_final.pdf>. Accessed 21 August 2006.

Tomme, Lt Col Edward, Lt Col, USAF. *Near-Space as a Combat Effects Enabler*. CADRE Quick-Look 04-25, College of Aerospace Doctrine, Research and Education (CADRE), (Maxwell AFB, AL: Air University, 2004). URL: <www.au.af.mil/au/awc/awcgate/cadre/ari_ql2004-25.pdf>. Accessed 19 November 2006.

Tomme, Lt Col Edward, USAF. *The Paradigm Shift to Effects-Based Space: Near Space as a Combat Effects Enabler*. Research paper 2005-01, CADRE, (Maxwell AFB, AL: Air University, 2005). URL: <www.au.af.mil/au/awc/awcgate/cadre/ari_2005-01.pdf>. Accessed 22 August 2006.

U.S. Centennial of Flight Commission. "Aviation History Facts: April." Web-only essay. URL: <www.centennialofflight.gov/user/fact_apr.htm>. Accessed 22 October 2006.

U.S. Marine Corps Warfighting Lab. *Campaign Plan 2006*. Web-only essay. URL: <www.mcwl.usmc.mil/mcp/Chapts%201-4_6,%207/MCP-Ch%203-TechDev%2010%20Jul%2006.pdf>. Accessed 3 December 2006

Waldrop, Major, USAF, Air Force Space Command (AFSPC). *Legal Issues and Legal Regime Governing Near Space*. Point Paper, Peterson AFB, CO: AFSPC, 06 May 2006.

Weatherington, Dyke, Deputy, UAV Planning Task Force, Office of the Secretary of Defense, Under Secretary of Defense for Acquisition, Technology and Logistics (USD[AT&L]). *Unmanned Aircraft Systems Roadmap, 2005-2030.* URL: <www.acq.osd.mil/usd/Roadmap%20Final2 .pdf >. Accessed 30 August 2006.